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RESEARCH PAPER

Growing Cloned Teak Seedlings for Small-Scale Farmers in Costa Rica

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Abstract This paper investigates the profitability of cloned teak seedlings among small-scale farmers in the Canton of Hojancha in Costa Rica. A survey was conducted among small-scale farmers to explore their opinions regarding tree breeding. Most respondents considered that the use of improved seedling material is profitable and their willingness to plant clones in the future was high. The net present value of teak plantations at a 5% discount rate was estimated to be USD 12,330, USD 12,814, USD 14,284 and USD 14,308 per hectare for four non-genetically modified seedling plantations. According to a sensitivity analysis, the profitability of a teak plantation based on non-genetically modified seedlings is more sensitive to changes in timber prices than to changes in silvicultural costs. Investment in clone planting appears potentially highly profitable. With interest rates of 5 and 3%, it was profitable to plant clones if only 1% of genetic gain in volume was achieved and if the price of the clones was not greater than 50% of non-genetically modified seedlings.

Keywords Tree breeding · Financial analysis

Introduction

Since the middle of the twentieth century, the deforestation rate in Costa Rica has been one of the highest in the world. The trend has slowed down in part due to major changes in the country's forestry legislation and policy (Hirvonen and Kanninen 2003). During the past 10 years or so, Costa Rica's forest area has slightly increased due the recovery of semi-natural forests and an increase in the area of plantations (FAO 2008). The predominant species in tree plantations is *Gmelina arborea*,

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accounting for 35.7% of the plantation area. Teak (*Tectona grandis)* covers about 15% of the plantations (FAO 2008).

Teak occurs naturally in Asian countries including India, Burma, Thailand and Laos (Wellendorf and Kaosa-Ard 1988). It is a highly demanding plantation species as regards soil and light, but performs well in plantations when the conditions are favourable, and indeed better than many tropical hardwood species (Pandey and Brown 2000). Consequently, it requires intensive management, including weeding at an early age (Puolakka 2003). The total area of teak plantations in Costa Rica is approximately 30,000 ha (Bermejo et al. 2004). Plantations have been established both with funds from international investment and forest-industry companies and jointly by Costa Rican and foreign investors.

Only a few economic studies have been published on teak plantations in Costa Rica. According to Pérez (2005), the need for reliable and objective information is especially important for the growing number of investors representing the private sector, particularly small-scale landowners, who may lack the means or the knowledge to carry out their own assessments of the potential risks and rewards associated with teak plantations. Bermejo et al. (2004) stated that on average quality sites in Guanacaste, Costa Rica, the typical growth rate of teak (8.6 m^3/ha/year) with 25-year rotations is profitable and does not need to increase further to attract investors. Nieuwenhuyse et al. (2000) showed that in the northern Atlantic lowlands of Costa Rica teak and gmelina plantations are financially attractive land-use options whereas managed natural forest is not. They also found that the area under teak plantations is relatively insensitive to price changes.

Normally, large-scale landowners have much more money at their disposal for investing in infrastructure and labour, and with larger plantation areas the costs per hectare are also lower (Puolakka 2003). Many small-scale landowners in developing countries hold the view that teak timber produced from their plantations fetches a lower price than that from large-scale landowners (Thulasidas and Bhat 2009). In the Philippines, severe pruning and the lack of thinning in woodlots reduce timber yield and quality (Bertomeu 2006). Also in India, lack of appropriate silvicultural practices in small-scale teak plantations caused the production of more defective logs, adversely affecting the market price of timber (Thulasidas and Bhat 2009).

Low quality seedlings are often another source of low profitability. Seedling quality can be improved by tree breeding. Tree breeding is highly effective in the tropics, where fast growth and early flowering of many plantation tree species allow direct improvement of trees by means of selection, and the breeding of superior genotypes can be done in a relatively short time, of 10–20 years. Genetic improvement can yield gains of 10% or more in volume growth during the first generation (Evans 1992).

Genetic gain is achieved by several interrelated characteristics—e.g. greater adaptability, increased volume production and higher wood quality—and all of these should be translated into monetary terms and used in financial analysis. However, it is difficult to place a value on all types of gain, and so most of the research focuses on only one or two sources of gain (Zobel and Talbert 1984; Ahtikoski 2000). Consistent with this literature, the focus in this paper is on more rapid volume growth due to genetic improvement.

Zobel and Talbert (1984) reviewed previous studies in terms of how much genetic gain is needed to justify a tree-breeding program. Davis (1967) calculated that a 2.5–4% volume gain over standard material would justify loblolly pine being grown using improved seed material in the southern USA. Carlisle and Teich (1970) stated that 2–5% genetic gain in volume would offset the additional costs of a tree-breeding program in Canada. The actual volume gains reported for the studied tree species and conditions more than offset such costs (Carlisle and Teich 1978), Zobel and Talbert 1984).

The first aim of this study was to clarify the profitability of small-scale teak plantations in the Canton of Hojancha, Costa Rica. The second aim was to study local farmers' attitudes regarding tree breeding and the use of clonal teak material in reforestation. A further aim was to find out how much genetic gain clones should yield for investments in planting clones, compared to non-genetically modified seedlings, to be profitable.

The Study Area

The study area is situated in the canton of Hojancha, which is located in northern Costa Rica on the Peninsula of Nicoya (Fig. 1). It is the smallest and least populated canton in the Province of Guanacaste. Most of the canton is mountainous terrain, composed of cattle ranches, and farming land, much of which has been planted with commercial timber species, including teak, *Gmelina arborea* and native species. The area of the canton is 261.8 km^2 and it has a population of 7,289 (INEC 2008), of which more than half live in Hojancha, the canton's capital. The official

Fig. 1 Location of the study area

tree-growers' organization is Centro Agrícola Cantonal de Hojancha (CACH). It was established in 1978, when degradation of the forests in the area was very severe. The role of CACH was central to this study, because the small-scale farms interviewed were selected from those who were working with the organisation. In addition, CACH offered many documents regarding teak farming in the area.

Financial Analysis Method

In this study, profitability of clone teak plantations was compared with teak plantations established using standard seedlings. First, the financial profitability of a particular teak plantation was calculated using default growth, yield, and cost parameters. Conventional criteria for comparing investment alternatives were used in this study and the methods were net present value (NPV), internal rate of return (IRR), and equivalent annual annuity (EAA). Planting clones can be seen as a typical production investment alternative for growers with high capital outlays at present being borne in order to obtain higher revenue in later years. The genetic gains were assumed to generate faster volume growth and result in an increase in the NPV output.

The net present value, as defined in Eq. 1, is the present value of revenues minus the present value of costs (Klemperer 1996). If the NPV is positive, the investment generates greater benefits than costs to the investor at the selected interest rate. The NPV was adopted as the measure of financial performance of teak plantations established using standard seedlings and then to assess the financial performance of clone planting investment.

$$\mathrm{NPV} = \sum_{y=0}^{n} \left[\frac{\mathrm{R}_y}{(1+r)^y} - \frac{\mathrm{C}_y}{(1+r)^y} \right] \tag{1}$$

R_y = Revenues in year y, C_y = costs in year y, $y = 0,1,2,\ldots,n$, r = estimated discount rate.

Using the internal rate of return (IRR) in Eq. 2 is another common way for evaluating investments. The IRR of the investment is the discount rate at which the present value of the net revenues equal 0, or where the NPV equals 0 (Klemperer 1996). An investment is acceptable if its IRR is greater than or equal to the investor's minimum acceptable rate of return. The IRR was assessed for standard seedling plantations and clone plantations. The equivalent annual annuity (EAA) (Eq. 2) is a method suitable for comparing teak plantation projects with different life spans. The EAA is an annual real income with the same present value, over the project's life, as its NPV (Klemperer 1996). The EAA is a valid ranking criterion for projects, if projects with shorter life spans can be repeated with their IRRs for the life span of longer projects. It is useful when comparing tree planting to land uses for which revenue is received annually.

$$\mathrm{EAA} = \mathrm{NPV}\frac{r}{1-(1+r)^{-n}} \tag{2}$$

Equal growth advantage percentages were assumed to occur every year until the final cut, and thereby result in a similar volume (m^3) advantage in every thinning. This is the so-called *constant volume advantage method*, and it leaves the harvesting times unchanged increasing only the volume yields of the harvesting operations, and thus usually results in NPVs which can be considered to be the 'lower boundaries' for a given genetic gain (Ahtikoski 2000).

Assessments were made considering the higher plantation establishment costs when using clonal seedlings. Because there are only estimations of possible clone prices in Hojancha, different seedling price options were tested. With every clonal seedling price, a particular percentage of genetic gain in volume growth is needed for the NPVs to be equal to that of a standard plantation. Sensitivity analysis was used for testing the effects of changes in timber prices, plantation establishment costs, maintenance costs, and discount rate. Sensitivity analyses are of great importance in financial analysis, because there is always some degree of risk associated with investments (Klemperer 1996; Niskanen 1998; Ahtikoski 2000).

Plantation Models and Cost Data

Four general growth models were adopted from teak growth and yield tables presented by Fonseca González (2004). These include two planting densities (1,111 and 816 trees per hectare) and two site indexes related to the maximum basal area (18 and 20 m^2 per hectare). Later, these models are called: 18/1111, 18/816, 20/1111 and 20/816. The growth and thinning models used are not intended to be optimal levels, but merely examples; the site with maximum basal area has better growth conditions than the other site. The growth tables report plantation age, extracted volume, and average breast height diameters for each harvest. These were used to calculate the cutting revenues from each harvest. Trees of different sizes have a different distribution of commercial logs. The cutting revenues were calculated according to average harvesting diameter when using growth models and data on the distribution of commercial volume in boles, which were adapted from Puolakka (2003). When estimating the NPVs a constant relative volume advantage for every cutting in the clone plantation was assumed.

The plantation establishment and maintenance costs for teak plantations in Hojancha used in this study were examined by CACH (2006). Data were collected from the Forest Stewardship Council -certificated plantations of the largest private landowner in Hojancha and these can be considered to be normal plantation costs in the area. It was assumed that the smallest landowners have the same costs although they probably do much work themselves in order to save costs.

Land procurement costs were not included in the analyses. It was assumed that teak plantations had been established on grazing land on the low production potential sites, which hence had a low opportunity cost. For example in South-East Asia, the profitability of tree plantations was not dependent on the opportunity cost of land (Niskanen and Saastamoinen 1996). Also, the timber price data were taken from the calculations of CACH (2006).

Because CACH's cost data covered only the first 12 years of plantation life, the costs for subsequent years were estimated. According to the literature, most of the

costs incurred with teak plantations occur during the first 10 years of the rotation (Puolakka 2003; Fonseca González 2004), and so it was assumed that all of the annual costs from the 6th year to the end of the rotation were constant. Cost data from CACH were for a plantation of 816 stems per hectare sph (spacing of 3.5 m $\times$ 3.5 m). These costs had to be adjusted for plantations of 1,111 sph (spacing of 3 m $\times$ 3 m). It was estimated that, in addition to higher seedling prices, denser plantations involve 20% higher establishment and maintenance costs during the first 4 years, but thereafter the costs for both plantations are the same. All money calculations are based on the value of USD in 2006, and have been converted from the applying the May 2006 exchange rate of USD 1.00 = 507 Costa Rican Colon (CRC).

Subsidies and taxes may have a great influence on the financial viability of small scale investors so the existence of these was investigated. Environmental payment system funds distributed among private teak producers in Hojancha are included in the calculations. The National Forestry Financing Fund (FONAFIFO) in Costa Rica provides a grant to forest owners if they reforest, preserve or use their forests in a sustainable way (Malavasi 2002; Hirvonen and Kanninen 2003). These funds are paid for environmental services including protection of water resources, biodiversity and landscape and sequestering carbon (Hirvonen and Kanninen 2003). Teak plantations are included in FONAFIFO's reforestation option and in year 2006 the amount distributed as subsidies for reforestation was USD 816/ha. According to FONAFIFO's website and CACH calculations, 46% of the subsidy is paid in the planting year, and 6% is paid every year from the first to the 10th year from planting. Since there are no taxes for private forest owners to pay, there is no need to include any taxes in the calculations.

The Survey of Small-Scale Teak Farmers

A survey was conducted among small-scale teak farmers by means of personal interviews in May 2006. The questionnaire was developed and revised by researchers and local authorities; the final instrument included 22 questions. The respondents were randomly chosen from among teak planters who had concluded reforestation contracts with CACH during 2001–2005 and from among people who were intending to plant trees in 2006. A total of 20 persons, 19 farm owners and one representative of a farm owner, were chosen from among approximately 70 growers, who had reforestation and environmental service payment contracts and plantations of *Tectona grandis* (teak), *Gmelina arborea, Bombacopsis quinatun* and *Schizolobium parahibum*. No one refused to be interviewed. The respondents in the study were private landowners, and one of them was a representative of the Hojancha Elementary School, which had agricultural land for educational and revenue-earning purposes. The representatives and their family members totalled 93 persons, and the average farming family was composed of 4.9 persons.

Interviews were conducted in Spanish with occasional help from an assistant. The respondents were asked in detail about teak plantations, the use of selected seedlings, and their willingness to use teak clones in the future. Also, some basic questions about their farm were included. Most of the questions were open-ended,

and the respondents could not choose any given response alternatives, but there were also questions to which the respondents could choose an answer from among given alternatives.

Results

Survey of Teak as an Element of the Land-Use Mosaic

The survey among the farmers showed that the total land area being managed by the 20 respondents amounted to 2215.4 ha, almost half of which was on one farm, while the median size of the estates was 29 ha. The largest land-use form by area was ‘Forest or Conservation’ accounting for 794.5 ha and 36% of all the respondents’ land area. It covered primary and secondary forest areas for wood production, and conservation areas. Cattle husbandry and pasture covered 600.9 ha and 27% of the area and it was the second largest land use form. Teak plantations were the third largest land use form occupying 580.2 ha and 26% of the total land area. The class termed ‘Crops and Others’ covered 3% of the total land area. It consisted of orange, mango and coffee cultivations, and also land under infrastructure, including roads and power lines. *Gmelina arborea* plantations covered 6% and pure plantations of native tree species including *Bombacopsis quantum* and *Jacaranda mimosifolia* covered 1% of the total land area.

Attitudes Regarding Teak as a Cash Crop

Of the 20 interviewees, 95% answered the question: ‘Why are you growing teak and not some other species?’. The respondents answered in their own words and most of them stated several reasons. Many of the most prevailing answers were more or less related to the economic benefits of teak (Table 1). One interviewed farmer was clearly not in favour of teak. He did not grow teak because of the higher erosion risk

Table 1 Respondents’ concepts regarding teak and reasons for planting teak ($n = 19$)

Reason for growing/not growing or planning to/not planning to plant teak	Relative frequency (%)
Because of a good price for the wood	58
Because it is more profitable than other species	37
Because it has good global markets	37
Because of the conditions of my estate, e.g. topography is good for teak	32
Because it is a fast growing species	26
Because management of teak is well understood and easy	16
Because I like the look of teak	11
Because teak is not susceptible to diseases	5
Because teak causes erosion	5
Because the price of teak wood is too high for many people	5

associated with teak plantations and he considered teak wood to be too expensive for his fellow countrymen.

All teak growers agreed that teak was a financially good investment. When asked to compare teak to other species, nine respondents (45%) stated that there is no more profitable tree or agricultural species to grow than teak, four (20%) answered that there are species with about the same profitability, and seven (35%) said that there are species with higher profitability. Some respondents also explained the reasons according to which they ranked materials and alternative land-use investments (Table 2). However, seven of the 20 interviewees did not give any explanation. The most common answer, given by 69% (9) of the respondents, was that the other species need longer rotation times than teak.

Opinions About Tree Breeding

The respondents were asked their opinions about tree breeding and the use of clones. It was most common to use certified teak seedlings from plus trees, because most of the nurseries were producing them. Plus trees are selected parent trees with desirable characteristics, e.g. in volume growth and trunk form. However, many respondents had older plantations grown from unimproved material. At the time of the field work for this study, the aim of CACH (Centro Agrícola Cantonal de Hojancha) was to launch clone production in the near future, and it had already organized education about tree breeding for local growers. Knowledge about the stages of tree breeding varied among the respondents: 80% of the respondents (16) believed that using selected seedlings from plus trees is a good investment, 20% (4) answered that they did not have knowledge of improved material and so could not say if using clones would be financially viable.

The growers were asked how much more revenue they would expect to earn from the use of genetically-improved selected seedlings from plus trees compared to traditional seedlings when establishing plantations. The question was: 'How much money do you except to earn over the rotation?', and thus it describes more a sum of net revenues over the rotation per one hectare than the net present value of the plantation over the rotation. It was supposed that farmers knew more or less accurately the costs of the plantation (because many of them were interested in planting) and that they had some knowledge about timber prices, and so they were

Table 2 Respondents' statements regarding more profitable tree or crop species ($n = 13$)

Explanation	Relative frequency (%)
Other species need a longer rotation	69
The species with the same or greater profitability can be more difficult to cultivate	31
Other species yield profits earlier	8
A more profitable form of land use needs a larger area of land	8
Some native species have much more ecological and thus also economical value	8

asked about net revenues instead of net present values or other financial performance criteria, with which they were perhaps not familiar. Questions about profitability expectations were particularly difficult for respondents, and the answers varied greatly. There were differences due to variable knowledge and experiences about teak crops among the respondents. The average difference between non-genetically-modified and selected seedling material from plus trees was USD 5,479 (28%) in this study in favour of selected material. The respondents' expectations for non-genetically-modified teak plantations averaged USD 19,505/ha (variation between USD 7,890 and USD 39,448, with the median being USD 13,807) and for selected teak plantations the average was USD 24,984/ha (variation between USD 9,862 and USD 55,227, the median being USD 18,738).

When asked about clones, some of the respondents said that they did not have any or much knowledge about clones. In any case, 60% of the respondents (12) stated that they will plant teak clones in the future and 19% stated that they may plant teak clones. Only one respondent (6%) was sure that he would not be planting teak clones. About 14 growers (70% of the interviewed growers) agreed when asked if they think they can earn more money with clone teaks than with standard plantation material or seedlings from plus trees. Six growers (30%) neither agreed nor disagreed. Next, the agreeing respondents were asked for the reasons why they expected to earn more money with clone plantations. The most commonly given reason was the better quality of the clone trees (77% of the respondents). This was followed by faster growth and greater profitability of cloned trees (each 46%). Also, better price of wood and lower costs of management (each 8%) were mentioned. One respondent (8%) noted that the profitability of tree plantations depends, along with genetic quality of trees, on site and soil quality, and management of the plantation.

Financial Profitability of a Non-Genetically-Modified Teak Plantation

The net present values of the various growing and thinning regimes studied demonstrate the differences in the growth potential of the site and the different volume yields of the regimes due to planting densities. The NPVs of the better sites (maximum basal area 20 m^2) are considerably higher because of the higher growth, and the total volume yields are bigger in the plantations with higher initial densities (Table 3).

Table 3 IRR (%), NPV (USD/ha), and EAA (USD/ha) at different discount rates for the studied teak plantation growing and thinning regimes

Applied rotation time	Plantation model	NPV 3% NPV	5%	NPV 8%	EAA 3%	EAA 5%	EAA 8%	IRR (%)
26	18/1111	18,535	12,814	7,742	1,037	891	716	54
25	18/816	17,564	12,330	7,608	1,009	875	713	68
28	20/1111	21,226	14,308	8,398	1,131	960	760	55
29	20/816	21,433	14,284	8,268	1,117	943	741	65

Note. In the models, maximum basal area (18 m^2 or 20 m^2) refers to the relative competitiveness of the sites and 816 or 1,111 (spacing of 3.5 m × 3.5 m or 3 m × 3 m) is the initial planting density.

In addition to testing different discount rates, the effect of changes in timber prices and silvicultural costs were tested by conducting sensitivity analyses. Total revenue is more sensitive to changes in timber prices that to changes in silvicultural costs (Table 4). One reason for this is because total revenue is greater than total costs. Changes in timber prices, thus, have a great impact on profitability.

Financial Performance of Clone-Planting Investment

Clone-planting profitability calculations were made using 10, 50, 100, 200, 300, and 400% higher seedling price estimates. With each initial price investment, a certain genetic gain in volume percent was needed for the net present values of the additional revenue to equal these costs. With interest rates of 3 and 5%, it was profitable to plant clones if only 1% genetic gain in volume was achieved in all of

Table 4 The results of sensitivity analyses conducted on four teak plantations. The last two columns refer to changes in NPV/IRR

Plantation model	Variables	A NPV (USD/ha)	A IRR (%-point)
18/1111	Timber prices		
NPV:12814	+20%	+2,674	+5.4
IRR:54%	−20%	−2,674	−5.3
	Silvicultural costs		
	+20%	−210	−8.0
	−20%	+210	+13.1
18/816	Timber prices		
NPV:12330	+20%	+2,550	+6.4
IRR:68%	−20%	−2,550	−5.8
	Silvicultural costs		
	+20%	−195	−12.7
	−20%	+ 195	+27.8
20/1111	Timber prices		
NPV:14308	+20%	+2,976	+5.0
IRR:55%	−20%	−2,976	−5.7
	Silvicultural costs		
	+20%	−213	−8.0
	−20%	+213	+13.1
20/816	Timber prices		
NPV:14284	+20%	+2,948	+5.5
IRR:65%	−20%	−2,948	−6.3
	Silvicultural costs		
	+20%	−202	−12.2
	−20%	+202	+27.2

the plantation models when the price of the clones was not higher than 50% compared to standard seedlings. If the clones were not more than 50% more expensive compared to non-genetically-modified seedlings, it was even profitable with 8% discount rate to plant clones possessing 1% genetic gain in a plantation scheme of 816 trees per hectare and 20 m^2 in basal area. When dealing with higher clone prices, more genetic gain was needed. For example, with clones three times more expensive than non-genetically-modified seedlings and when using a discount rate of 5%, the genetic gain needed was 4 and 3%, respectively with plantation densities of 1,111 and 816 per hectare and both growing sites. When using a discount rate of 5%, it was also observed that the required genetic gains were equal for 10, 50, and 100% higher clone prices for all plantation models, but not for the 200, 300, and 400% higher clone prices. Changes in plantation maintenance and establishment costs did not have any effect on the profitability between the two alternatives, because the costs were assumed to be the same for both seedling materials.

When timber prices and growth increase or decrease simultaneously, it has a great impact on cutting revenues, and thereby on the NPVs (Tables 5, 6). Moreover, if the prices decrease, it will make clone planting less profitable because the additional revenues also decrease, and thus the profitability difference with non-genetically-modified plantation decreases (Table 4). While Table 4 shows the absolute values (changes in USD/ha or IRR %-point), in Tables 5 and 6 the results are shown in regard to genetic gain threshold limits. Changes occurred in the gray range (5% discount rate). For example, if timber prices increase 20%, it makes clone planting as an investment profitable with 1% genetic gain instead of 2% genetic gain when timber prices are constant (Table 5). It should be noted that the changes in all of the plantation models are quite similar, albeit that the limits of some models change with lower price differences than others. This is because of the present rounding of units.

Although it was mentioned earlier that comparing the financial profitability of the different plantation densities should be done with caution, it was found that the profitability order changed in some cases when using clones. Calculating EAAs of 8% it became evident that the profitability of plantation model 18/816 offsets model 18/1111 when the clone price is 100% higher compared to non-genetically-modified seedlings and the genetic gain is less than or equal to 10%. With clone price being 200% higher, the more widely-spaced plantation was more profitable until 50%

Table 5 The effect of a 20% increase in timber prices on genetic-gain threshold limits

Plantation model	Clone seedling price (% above non-genetically-modified seedling price)					
	10%	50%	100%	200%	300%	400%
18/1111	1	1	2	3	5	6
18/816	1	1	2	3	4	5
20/1111	1	1	2	3	4	6
20/816	1	1	1	2	3	4

Table 6 The effect of the 20% decrease in timber prices on genetic-gain threshold limits

Plantation model	Clone seedling price (% above non-genetically-modified seedling price)					
	10%	50%	100%	200%	300%	400%
18/1111	1	2	3	5	7	9
18/816	1	1	2	3	5	7
20/1111	1	1	2	4	6	8
20/816	1	1	2	3	5	6

Table 7 The genetic-gain threshold values needed if making the final cut at the time of the third thinning (discount rate 5%)

Plantation model	Higher price clone seedling					
	10%	50%	100%	200%	300%	400%
18/1111	1	2	3	6	8	11
18/816	1	1	2	4	5	7
18/1111	1	2	3	5	7	9
20/816	1	1	2	3	5	7

genetic gain, which was the last unit simulated. Nevertheless, the EAAs plantation model 20/1111 were higher than those of 20/816 until 400% higher clone price, and with genetic gain more than or equal to 15%. However, it can be said that the higher price of the clones and the higher discount rate used, using clones is proportionally more profitable with more widely-spaced plantations.

The profitability of clone planting when using shorter rotation times was tested by making the final cut and cutting the total volume at the time of the third thinning. Higher genetic gain was needed for the clone planting investment to be profitable (Table 7). This is because more additional growth is then lost. Again, less genetic gain is needed for lower-density plantations.

Discussion and Conclusions

Small-Scale Teak Farmer Survey

Financial reasons were clearly the reasons for growing teak plantations or intending to plant teak. Most of the respondents considered planting teak to be a very good investment. In any case, slightly more than half of the respondents mentioned that there may be other tree species enabling about the same or higher profitability. Teak was prioritised over other species by most of the respondents because of its fast growth and ease of growing as a crop. The results indicate that growers are very aware of the financial profitability of various tree species and that fast profits are considered to be important. It should be acknowledged, however, that because the

present sample of small-scale farmers only included farmers, who clearly must believe that teak is a good investment, the results may be biased in favour of teak farming.

Most of the respondents considered that using selected seedlings from plus tree parents is a good investment and can yield better profitability than standard seedlings. The reasons for this were firstly the better quality of the logs and secondly faster tree growth. The median respondents expected USD 13,807/ha net income from standard teak plantations and 36% higher net income from plantations established using selected seedling. Information about the monetary expectations is insufficient for proper comparisons with the financial analysis because the rotation length and degree of thinning were not included in the questions, and the answers varied greatly. The net incomes provided by the financial analyses of the four plantation models were almost three times higher. However, growers in Hojancha tended to make the final cuttings much earlier than what officially recommended rotations would be. Net income that is 36% higher from 36% genetic gain in volume may be seen quite optimistic, but respondents also expected higher revenues from the higher quality of the timber and the lower costs of genetically-improved plantations.

Hojancha growers are very interested in using clone teak in establishing future plantations since most of the respondents (75% of all interviewed tree growers) were going to or possibly going to plant clones. The tree growers suspected that clone teak seedlings may have some disadvantages as well; presumably the most obvious disadvantage would have been the high price. If clone seedlings are much more expensive or difficult to get, it is possible that only the richest growers can really afford to plant them. In the future, the tree growers' organization CACH has a major role to play in guaranteeing that all growers can benefit from tree breeding and can afford or get loans for planting clones. This is the case everywhere in the world: the best material and techniques should be made available for small-scale farmers.

Based on the results from the survey, it seems that teak growers might have a lower discount rate than the rates examined in our analysis. Evidence of a low discount rate can be seen first in the way survey respondents prefer teak because it requires a shorter rotation than other species, and second in the way owners tend to make final cuttings much earlier than what was recommended. According to Ducla-Soares et al. (2001), forest owners do not often behave as excepted, anticipating the cutting time, and thus, frustrating the predictions of the Faustmann model based on constant discounting. For example, landowners in Mississippi prefer shorter term forest investments and accept lower rates of return for shorter forest projects than for those lasting 25 years (Bullard et al. 2002). In this case, tree growers prefer teak to other crops also because risks are lower. The respondents valued to grow teak more because of good price, global markets and profitability than because it is a fast growing species (Table 1). All these reasons reduce the risks of investment.

Financial Performance of Plantations

Given the interest rates applied in this study, the NPVs and equivalent annual annuities demonstrate the superiority of higher planting densities as well as the

significance of the interest rates used. It becomes apparent that with a lower growth potential site and the prevailing thinning regime it is almost as profitable to plant 816 trees per hectare as 1,111 trees per hectare applying a discount rate of 8% (Table 3). It should be noted here that this is mainly due to the larger diameters, and thus the higher cutting revenues from early thinning of the more widely-spaced plantations.

The IRR results in Table 3 are strongly affected by the net revenues and costs in first years, for example higher establishment costs of the more closely-spaced plantations. Also if land acquisition costs were included in the study, the IRR criteria would probably give a different ranking for the different models. As Gansner and Larsen (1969) have suggested, forest economists and others, who use the IRR to rank the financial desirability of alternative investments in timber production, must use this economic tool with care. Unambiguous comparison of the profitability of different degrees of thinning intensity based on IRR would need normalization of size and shorter projects could be repeated applying the IRR for longer ones (Klemperer 1996; Nautiyal 1988). It is important to understand that these different growth models are not fully comparable as investments. Instead, the purpose in using them is to present some examples of the financial profitability of teak in Costa Rica under four circumstances. Also, the optimum rotation times can be considerably shorter. Although we used the best available growth and yield data in this study, as well as the best available data for estimating the profitability of the clones, we strongly recommend for updating of the data when conducting further studies, especially as then more experience will have accumulated concerning teak farming in Hojancha.

Some remarks according to the IRR criterion can be made. According to the IRR, more widely spaced plantations are more profitable than more closely placed plantations (Table 4). Similar results were found by Feng-shan (2001), who found out that decrease with afforestation density increased IRR in most cases in *Larix olgesis* pulp forests. In the present study, when site class increased, the IRR increased in the case of higher initial density plantation but not in the case of wider initial density plantation. When looking at the rotation times of wider density plantation, we can notice that rotation time of plantation model 18/816 is 4 years shorter than the one of plantation model 20/816.

In many cases small-scale forest farmers have little influence in determining prices and supply arrangements for their log sales. They are dependent on market prices for logs normally set by large commercial suppliers negotiating with large log processors (Quayle 2003). For example Bertomeu (2006) has suggested that tree growers' access to markets can be improved by developing cooperatives that enhance the economies of scale of timber production and facilitate market information. In this case, the official tree-growers' organization CACH is responsible for taking care of silvicultural counseling and market information for small-scale farmers. Therefore, also the price data collected from the FSC-certificated plantation in study area can be seen as trustworthy.

De Vriend (1998) calculated various NPVs in Costa Rican teak plantations ranging from USD 11,727 per hectare to USD 31,555 with an interest rate of 8%. In the present study, the NPVs of 8% discount rates are lower, but De Vriend does not

present any information on land procurement costs and rotation periods used in the study. Also, Pandey and Brown (2000) have warned against overestimating teak's potential, which is currently damaging the image of teak for angry investors, who are not getting what they were 'promised' at the end of the rotations.

Using superior seedling material, here this material being comprised of teak clones, was clearly shown to be profitable for the private tree growers. Clones can cost much more than standard seedlings, if their genetic gain in volume reaches a certain percentage. Likely questions would be the following: What would be the most probable clone price compared to standard seedlings? What would be the most probable genetic gain? In practice, clone prices could be 50% higher than those of standard seedling. Genetic gain not exceeding 2, 2, 2 and 1% would be needed for different plantation models with 50% higher clone price even when applying a discount rate of 8% in order for clone planting to be worthwhile. The genetic gains would easily be far greater. Murillo and Badilla (2005) have presented an estimate of 20% genetic gain in volume in Costa Rica when using superior genetic material; namely, clones. In addition, the authors pointed out that the highest increase takes place in timber of better quality and higher price, thus increasing cutting revenues.

Constant volume growth method was used in this study. Real situation may be different; for example tree breeding may increase the volume growth of young trees more than old trees. If this would be the real situation, our profitability estimates would be lightly overestimated. On the other hand other benefits from tree breeding were not simulated, which all affect profitability. According to Kjaer and Foster (1996), quality characters such as stem straightness, absence of epicormic shoots, long and clear bole, fluting, and colour are all very important traits of teak, and it may be possible to improve these through breeding. Consequently, it is a matter of dispute whether clone planting is a profitable investment if the total genetic gain in the different characteristics can be achieved even partly and if the clone seedling price does not increase too much. It can, then, be said that the present study provides only the 'lower boundary' of the profitability of clone planting.

The calculations show that if lower initial planting densities are used instead of higher initial densities, less genetic gain would be needed for profitable clone planting investment. Also, it was found that more genetic gain is needed if shorter rotation times are used. Kjaer and Foster (1996) stated that the economics of tree improvement will be most favourable on the best site, and this can also be seen here. It is important to inform the tree breeders, foresters, and growers that the genetic gain from the breeding could be lost when using inadequate rotation times or when applying overdense planting per hectare. Sensitivity analyses showed that changes in timber prices greatly affect profitability while changes in silvicultural costs do not have a major impact. Also, Puolakka (2003) has found that the profitability of a plantation project is most sensitive to changes in the price of timber. In general, the material costs are higher than labour costs also in plantations established using non-genetically-modified material. Tree breeding is most profitable when dealing tree species characterised by rapid growth and the high value of products made from their wood (Marquis 1973; Zobel and Talbert 1984). Teak certainly fulfils these conditions in Costa Rica.

In the present study, whereas the financial analysis used quantitative data and gave exact numeric results about economics, the survey findings produced also quantitative but more qualitative data about the real situation in Hojancha. The interviews made it possible to achieve a better understanding of important issues, which are not quantifiable and never become apparent within the calculations. It was necessary to clarify the attitudes of small-scale farmers concerning teak and tree breeding to facilitate the continuation of tree planting projects by the local tree growers' organization (CACH) and its socio-economic evaluation. Interviewing people other than teak farmers is something that we recommend to be included in further studies in order to gain more information about the social impacts of plantations. It can be concluded that teak has high potential as an investment in the Hojancha region and further promoting of improved seedling material in tree growing projects is warmly encouraged.

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